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Description

CARDIAC IMAGING SYSTEM AND METHOD FOR PLANNING MINIMALLY INVASIVE DIRECT CORONARY ARTERY BYPASS SURGERY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of United States provisional application No. 60/484,012, filed July 1, 2003, the contents of which are incorporated by reference herein in their entirety.

BACKGROUND OF THE INVENTION

[0002] The present disclosure relates generally to cardiac surgical bypass systems and, more particularly, to a cardiac imaging system and method for planning minimally invasive direct coronary artery bypass surgery (MIDCAB).

[0003] According to American Heart Association statistics, over 500,000 coronary artery bypass grafts (CABGs) are performed every year in the United States alone. In coronary

artery disease, the arteries that bring blood to the heart muscle (i.e., the coronary arteries) become clogged by plaque, which is a buildup of fat. During CABG surgery, the blood is rerouted around the clogged arteries in order to improve blood flow and oxygen to the heart. A healthy blood vessel, such as the left internal mammary, is detached from the chest wall and is thereafter used to circumvent the blocked area. Alternatively, a segment of vein from the leg can also be used for the CABG. One end of the vessel/vein is sewn onto the aorta (the large artery leaving the heart), while the other end is attached or "grafted" to the coronary artery beyond (or past or distal to) the blocked area. Patients may undergo multiple bypasses at the same time.

[0004] Cardiopulmonary bypass using a heart-lung machine is typically used to stop the movement of the heart at the time of the CABG procedure. Although CABG is the treatment of choice in many cases (and is one of the most common surgical procedures performed today), there are several potential complications from this surgery, as well as from the cardiopulmonary bypass technique required during the CABG procedure. In a recent study published in the New England Journal of Medicine, 53 percent of pa-

tients had diminished mental acuity at the time of discharge from the hospital after a CABG procedure. In addition to the prolonged hospital stay and the possible need for transfusions, sternal wound infection at the site of the incision can occur in 1 to 4 percent of patients and carries a mortality (death) rate of about 25 percent. Furthermore, as many as 8 percent of patients may develop kidney dysfunction as a result of the CABG procedure.

[0005] As a result of the above described problems associated with CABG, minimally invasive direct coronary artery bypass (MIDCAB) surgery has been used as an alternative in some patients, wherein the MIDCAB procedure does not require reliance on the heart-lung machine. In MIDCAB surgery, a 10-12 cm access incision is made in the patient's chest, after which several different instruments are used to stabilize the heart at the time of surgery. The surgeon then connects a graft to the diseased coronary arteries while the heart is beating without artificial support. Due to the nature of the operation, grafting (the attaching of the vessels) must be done under the surgeon's direct vision and the coronary artery that is to be bypassed must lie directly beneath the incision (surgical opening). Consequently, this procedure is currently used in only a limited

number of patients, and only if it is known that just one or two of the arteries require a bypass.

[0006] Although it is estimated that over 30 percent of patients who need CABG may be suitable candidates for MIDCAB surgery, presently the procedure is performed in only 10 percent of patients because of this unknown factor. There is, therefore, a distinct need for an improved system and method to make this procedure more effective and easier to perform.

BRIEF DESCRIPTION OF THE INVENTION

[0007] The above discussed and other drawbacks and deficiencies of the prior art are overcome or alleviated by a method for planning minimally invasive direct coronary artery bypass surgery (MIDCAB) for a patient. In an exemplary embodiment, the method includes obtaining acquisition data from a medical imaging system, and generating a 3D model of the coronary arteries and one or more cardiac chambers of interest. One or more anatomical landmarks are identified on the 3D model, and saved views of the 3D model are registered on an interventional system. One or more of the registered saved views are visualized with the interventional system.

[0008] In another embodiment, a method for planning minimally

invasive direct coronary artery bypass surgery (MIDCAB) for a patient includes obtaining acquisition data from a medical imaging system using a protocol directed toward the coronary arteries and left ventricle. The acquisition data is segmented using a 3D protocol so as to visualize the coronary arteries and the left ventricle. A 3D model of the coronary arteries and the left ventricle of the patient is generated, and one or more anatomical landmarks on the 3D model are identified. Saved views of the 3D model are registered on an interventional system, and one or more of the registered saved views are visualized the interventional system. The orientation and any anomalies associated with the coronary arteries and the left ventricle are identified from the 3D model.

[0009] In still another embodiment, a method for planning minimally invasive direct coronary artery bypass surgery (MIDCAB) for a patient includes obtaining acquisition data from a cardiac computed tomography (CT) imaging system using a protocol directed toward the coronary arteries and left ventricle. The acquisition data is segmented using a 3D protocol so as to visualize the coronary arteries and left ventricle, including interior views of the coronary arteries. A 3D model of the coronary arteries and left ventri-

cle of the patient is generated, and one or anatomical landmarks on the 3D model are identified. Saved views of the 3D model are registered on a fluoroscopy system, and one or more of the registered saved views are visualized with the fluoroscopy system. The orientation and any anomalies associated with the coronary arteries and the left ventricle are identified from the 3D model.

[0010] In still another embodiment, a system for planning minimally invasive direct coronary artery bypass surgery (MIDCAB) for a patient includes a medical imaging system for generating acquisition data, and an image generation subsystem for receiving the acquisition data and generating one or more images of the coronary arteries and the left ventricle of the patient. An operator console is configured for identifying one or more anatomical landmarks on one or more of the generated images, and a workstation includes post processing software for registering saved views of the 3D model on an interventional system. The interventional system is configured for visualizing one or more of the registered saved views therewith, quantifying distance and location information for a cardiac point of interest, and identifying an incision location and path for MIDCAB based on the quantified distance and location in-

formation for the cardiac point of interest.

Brief Description of the Drawings

[0011] Referring to the exemplary drawings wherein like elements are numbered alike in the several Figures:

[0012] Figure 1 is a schematic diagram of a medical imaging system, such as a computed tomography (CT) system, suitable for planning minimally invasive direct coronary artery bypass (MIDCAB), in accordance with an embodiment of the invention;

[0013] Figure 2 is a flow diagram of a method for planning minimally invasive direct coronary artery bypass (MIDCAB), in accordance with a further embodiment of the invention;

[0014] Figure 3 is an exemplary CT image of the chest and heart, on which distance and angles may be measured for MIDCAB planning; and

[0015] Figure 4 is a cardiac CT image showing necrosed LV due to myocardial infarction.

Detailed Description of the Invention

[0016] Disclosed herein is a cardiac imaging system and method for planning minimally invasive direct coronary artery bypass surgery (MIDCAB), so as to enable a practitioner (e.g., electrophysiologist, cardiologist, surgeon) to plan in ad-

vance the approach to take for the procedure. With more detailed 3D and navigator (interior) views, a geometric representation of the coronary arteries and the left ventricle (LV) is obtained with an imaging modality such as CT, magnetic resonance imaging or ultrasound. The practitioner can then identify the orientation, size, anomalies, and extent of blockage in the coronary arteries to be targeted for MIDCAB. Using this information, a more exact approach can be taken for the MIDCAB, with incisions made at the most appropriate sites, allowing for more areas to be targeted and, at the same time, allowing for smaller incisions.

[0017] Although the exemplary embodiments illustrated hereinafter are described in the context of a computed tomography (CT) imaging system, it will be appreciated that other imaging systems known in the art (e.g., magnetic resonance, ultrasound, 3D fluoroscopy) are also contemplated with regard to planning MIDCAB.

[0018] Referring now to Figure 1, there is shown an overview of an exemplary cardiac computed tomography (CT) system 100 with support for cardiac imaging. Again, it should be understood that the cardiac CT system 100 is presented by way of example only, since other imaging systems

known in the art (e.g., magnetic resonance, ultrasound, 3D fluoroscopy) may also be used in an embodiment of the present invention. A scanner portion 102 of the system 100 includes an EKG monitor 104 that outputs Revents into a scanner 106 through a scanner interface board 108. A suitable example of scanner interface board 108 is a Gantry interface board, and can be used to couple an EKG system to the scanner. The cardiac CT subsystem defined by scanner portion 102 utilizes EKG-gated acquisition or image reconstruction capabilities to image the heart (and more specifically the coronary arteries and left ventricle) free of motion in its diastolic phase, as well as in multiple phases of systole and early diastole.

[0019] Data are outputted from the scanner portion 102 into a subsystem 110 that includes software for performing data acquisition, data control and image generation. In addition, data that is outputted from the scanner 106, including Rtime stamps, is stored in an acquisition database 112. Acquisition is performed according to one or more acquisition protocols that are optimized for imaging the heart and specifically the coronaries and LV in diastole and multiple phases in systole and early diastole. Image generation is performed using one or more optimized 3D

protocols for automated image segmentation of the CT image dataset for identifying the orientation, size and any anomalies of the coronary arteries. The 3D protocols are further optimized to generate navigator (interior) views of the coronaries to assess the size and extent of the lesions therein.

[0020] The image data stream 114 is sent to an operator console 116. The data used by software at the operator console 116 for exam prescription and visualization is stored in an image database 118, along with the data from the image data stream 114. Display screens 120 are provided to the operator of the exam prescription and visualization processes. The image data may be archived, put on film or sent over a network 122 to a workstation 124 for analysis and review, including 3D post processing. The post processing software depicted in the workstation 124 includes one or more optimized 3D protocols and short axis protocols from an automated image segmentation of the CT image dataset for the LV anatomy, movement of LV walls during systole (i.e., LV contractility), epicardial fat location, location of viable tissue, blood vessels and their branches and orientation.

[0021] The 3D protocols and short axis protocols of the post

processing software enable the software to provide views of the LV, including blood vessels, branches and slow motion cine of the LV, particularly the posterolateral wall or other areas of the LV. These special views and video (cine) clips may be saved into a 3D rendering of ventricle files 126 and LV short axis images 128 for use by the practitioner for interventional planning and procedure. The post processing software also provides for the export of detailed 3D models 130 of the thoracic wall and ventricle surfaces. The 3D models 130 (which may be implemented through color coding, contouring, movie views, etc.) may be viewed on display screen 132 associated with workstation 124 and are configured to include geometric markers inserted into the volume at landmarks of interest such that the thoracic wall and the LV are visualized in a translucent fashion with the opaque geometric landmarks.

[0022] In addition, the 3D models 130 may be in exported in any of several formats, including but not limited to: a wire mesh geometric model, a set of contours, a segmented volume of binary images, and a DICOM (Digital Imaging and Communications in Medicine) object using the radiation therapy (RT) DICOM object standard or similar object. Other formats known in the art can also be used to store

and export the 3D models 130.

[0023] Referring now to Figure 2, there is shown a flow diagram 200 illustrating a method for MIDCAB planning, in accordance with a further embodiment of the invention. Beginning at block 202, a volume of data is initially acquired on the cardiac CT system, using a protocol that is preferably optimized for the coronaries and LV regions of the heart. A continuous sequence of consecutive images is collected from a volume of a patient's data, in which a shorter scanning time using faster scanners and synchronization of the CT scanning with the QRS (peak) on the ECG (Electrocardiogram) signal will reduce motion artifacts (e.g. blurring, shadowing, streaking) in a beating organ like the heart. The ability to collect a volume of data with a short acquisition time allows reconstruction of images that have more precise depictions of anatomical landmarks, making them easier to understand.

[0024] At block 204, the image dataset is segmented with post-processing software using a 3D protocol and short axis protocols optimized for MIDCAB. Automated or semi-automated procedures may be employed, where appropriate, with or without queues from the operator. This operation can be performed on short axis reformatted cardiac

images for each phase and slice location to obtain the displacement profile, or on multiphase, long axis reformatted cardiac images.

[0025] Then, as shown in block 206, the coronary arteries and LV are visualized using 3D surface and/or volume rendering to create 3D models thereof that provide certain quantitative features of the coronaries and the ventricles such as contour, position, orientation, dimensions of the coronaries and the ventricles and, additionally, the function and the areas of scarred tissue of the ventricles. As shown in block 208, the orientation, size and extent of the lesions in the coronary arteries targeted for MIDCAB are identified. In this manner, the size and contour of the vessels as well as the size and extent of the lesions are measured and determined, as shown in block 210.

[0026] For example, Figure 3 illustrates an exemplary CT image of the chest and heart and their spatial relationship therebetween. Exact distances and angles may be measured in 3D for planning MIDCAB and, in addition, such information may also be used to generate thickness graphs or plots, as well as 3D geometric visualization for quick analysis. This information can contribute significantly to identification and isolation of the optimal path through

the chest wall.

[0027] Referring again to Figure 2, method 200 proceeds to block 212 for identification of anatomical landmarks over the thoracic wall, coronary arteries and ventricles. At block 214, explicit geometric markers are then inserted into the volume at landmarks of interest, wherein the markers may be visualized in a translucent fashion using 3D surface and/or volume rendering so as not to obscure the image. An example of such a visualization is presented in Figure 4, which illustrates a cardiac CT image showing a necrosed LV due to myocardial infarction. The specific images (e.g., Dicom images, video clips, films, etc.) are saved as desired for subsequent reference during the MIDCAB. As shown in block 216 of Figure 2, the saved views are then exported and registered with the computer workstation of the interventional system. After the registered images are imported, they may be visualized over the interventional system by the practitioner, as seen in block 218.

[0028] In addition to the registering markers, the workstation of the interventional system may also configured to register the instruments used for the specific MIDCAB procedure, as shown in block 220. Finally, the actual MIDCAB surgery

is performed at block 222.

[0029] It will be appreciated that automatic techniques may be employed to perform any of the above steps by using one or more of the several computer-assisted detection, localization and visualization methods available. Such steps may include, for example, quantitative analysis of defects, localized contractility profile (LV wall movement), and identification of blood vessels using the continuity of same intensity levels. Moreover, these methods could be either completely automatic when the procedure and the organ of interest is specified or partly interactive with input from the user.

[0030] It will further be appreciated that through the use of the above described method and system embodiments, the planning of MIDCAB is improved in that the imaging information generated and registered allows for an appropriately tailored approach to the interventional procedure. In choosing the appropriate approach, the duration of the procedure itself is reduced and any unnecessary procedures are also eliminated. More particularly, a detailed 3D geometric and axial representation of the coronary arteries and LV increases the precision of the MIDCAB procedure. The identification of necrosed myocardium, if any,

enables the practitioner to avoid such areas and determine an exact location of the incision is determined in advance before the surgery is performed.

[0031] The above described planning process thus reduces the amount of time required to perform the MIDCAB. Moreover, the identification of appropriate locations increases the efficacy of treatment and can reduce the risk of complications. After the procedure is completed, the data can be archived, read and processed in the form of CD-ROMs, floppy diskettes, hard drives or any other mediums used for this purpose as in the acquisition and transportation stages. Thus, the computer and the medium also become an apparatus for the purposes of the present invention.

[0032] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode

contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.